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Case Report

Incomplete decapitation in suicidal hanging – Report of a case and review of the literature

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Abstract

Complete or incomplete decapitation is an unusual complication of suicidal hanging. We present a case of incomplete decapitation due to hanging with soft tissue injuries, spinal cord dissection between C2 and C3, fracture of the hyoid bone and injuries of cartilages. The 52-year-old male victim with a 95 kg body mass used a 1.5 cm thick and 3.1 m long nylon rope snap-hooked to a rafter. The comprehensive literature review of incomplete or complete decapitation by suicidal hanging emphasises the importance of investigation of biomechanical process. In the presented case we calculated the physical parameters (final speed: 7.8 m/s, kinetic energy: 2945 J, force: 9500 N). The previous observations were confirmed that body weight and falling distance were the most important factors in the pathomechanism of decapitation. In the hanging process energy can be stored by changing the position of the human body in the gravitational field, by changing the shape of the hanging rope and by changing the motion of the hanging body. We concluded that the occurrence of complete or incomplete decapitation can increase by the increasing energy stored as potential energy at the starting position and the characteristics of the rope extended by the hanging body.

Keywords: Incomplete decapitation; Hanging; Stored potential energy; Energy transfer; Spring model

1. Introduction

Despite hanging being the most frequent method of suicides,[1,2] complete[3,4] or incomplete[5] decapitations are unusual complications of such hanging. In complete decapitation the head is totally severed from the trunk,[1] and separation of cervical vessels, muscle and nerve tears and lacerations,[3] severance of cervical vertebra between CV2 and CV3,[1,4] or CV1 and CV2[2,4] with the intervertebral disc injury can be observed. In incomplete decapitation there remain tissue connections with the trunk; but disruption of cervical spine and of most anatomical structures of the neck can be detected. The pathomechanism of incomplete or complete decapitation depends on several factors influenced by the movement and acceleration of body in hanging process.

In this report we describe a case with incomplete decapitation after suicidal hanging. Differences of physical parameters (body mass, length and elasticity of rope, potential, kinetic, and elastic energy) were examined in the comprehensive literature reported incomplete or complete decapitations.

2. Case history

The 52-year-old man was found in a storage building, hanging in a 1.5 cm thick nylon rope. The upper end of the rope was fixed at 5.1 m height. The length of the rope was 3.1 m from the point of fixation to the running knot of the noose. A 2.25 m long ladder was found near the body as a climbing aid. A suicidal letter was found by the police at the home of victim.

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2.1. Autopsy findings

The autopsy revealed the body (weight: 95 kg, height: 178 cm) of a male victim with marked post-mortem hypostasis. A nylon rope was located at the upper cervical region 2–3 cm below the mandible gonions. The wound showed a skin abrasion, 75–80 mm in width at the front (Fig. 1), and there were several fine parallel surface fissures at the abrasion. The neck was narrowed by the nylon rope to about 10 cm in diameter; however, the skin did not show separation. The severance line passed under the skin, and soft tissues of the neck were separated above the thyroid notch. The cervical spine was severed between C2 and C3, and the intervertebral disc was torn apart, the spinal cord and dura, all the muscles, cervical vessels and nerves were lacerated (Fig. 2). The hyoid bone showed multiple fractures, both superior horns of the thyroid cartilage were broken and the epiglottis was torn off and remained attached to the head (Fig. 3). There were several horizontal tears of the carotid arteries. Blood aspiration, acute emphysema of the lungs, excessive strain-induced bleeding and haemorrhages under the anterior longitudinal ligament in the cervical region were observed. Pathomorphological changes of natural diseases were not detected. Post-mortem blood and urine tested negative for alcohol, pharmaceuticals and drugs.

Fig. 1. A nylon rope was located at cervical region with skin abrasion, and several parallel surface fissures at the abrasion. The neck was narrowed by the rope to 10 cm in diameter; and the skin did not tear.

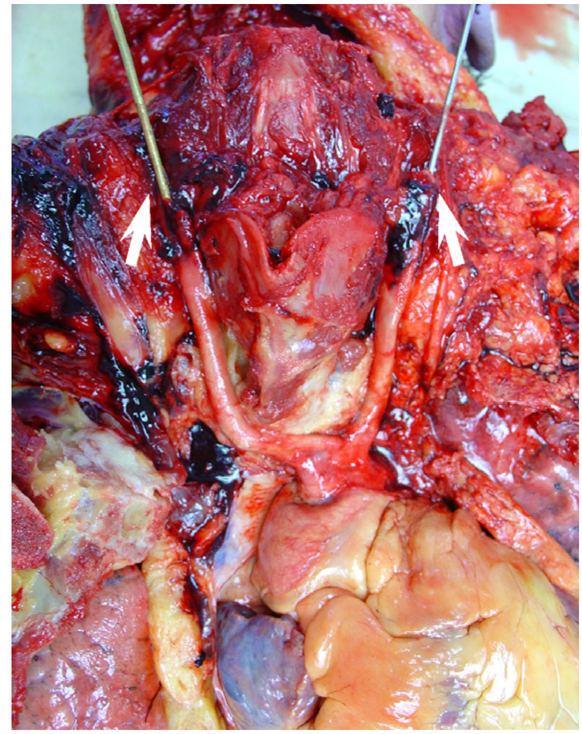

Fig. 2. Probes placed in the carotid arteries demonstrate the severe injuries. The severance line passed under the skin, the soft tissues of the neck were separated above the thyroid notch, the cervical spine was severed between C2 and C3, and the intervertebral disc was torn apart.

Fig. 3. The hyoid bone showed multiple fractures, both superior horns of the thyroid cartilage were broken, and the epiglottis was torn off and remained attached to the head.

3. Discussion

In this report we present a case of incomplete decapitation due to suicidal hanging. It has been pointed out that decapitation in hanging is a highly dynamic process with severe injuries.[1] Cervical fractures and spinal cord injuries[1–4] are uncommon complications of hanging, however, the victims suffer a wide range of soft tissue injuries.[6,7] The final cause of death is brain hypoxia.[1,2,8] In spite of the low incidence of complete or incomplete decapitation, a careful medico-legal investigation can differentiate between

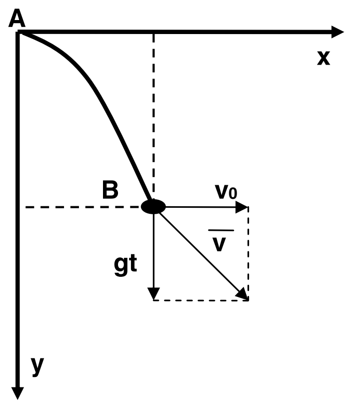

Fig. 4. The movement of hanging body from the starting point to the final position. A – Starting position of hanging. Potential energy at A point is: $E_{p(A)} = 1/2\,mV_0^2 + mgy$. The way in the horizontal direction is: $x = v_0 t$; and the speed in the horizontal direction does not change. The way in the vertical direction is: $y = 1/2gt^2$. B – Terminal position of hanging body. $E_{p(A)} = E_{k(B)}$. Kinetic energy at B point is: $E_{k(B)} = 1/2\,mV^2$.

accidental, suicidal and homicidal hanging. In addition, more emphasis is now placed on the application of physical parameters and their implications in the hanging process.

Fig. 4 demonstrates the way (x, y) and speed (v) of body, body mass (m), time (t) of hanging process. This figure illustrates the stores of energy (E_p, E_k) in the starting and final position. Usually the body movement in hanging is made by two separate motions. The free fall in the vertical direction from the point of release to the axis is given by $y = 1/2gt^2$, and another movement $x = v_0 t$ which starts when the victim rises off the starting point by sudden muscular effort, or by a push in homicidal cases. Based on the complexity of movement of jumping and free falling, the calculation of the initial speed seems to be very difficult.

In hanging cases the force (F) exerted by the rope on the neck at the final moment depends on body mass (m) and acceleration (a). The equation might well be written:

$$F = m\Delta v/\Delta t = ma$$

The $\Delta v/\Delta t$ is the rate of change of velocity or the acceleration produced by the force acting on the body. The fall heights were decided in dependence upon body mass and distance of negative acceleration.[9] Rabl et al.[10] found a force of about 12,000 Newton (N) according to their general estimations of load values leading to compete decapitation. The Newton defined as that force which gives to a body mass of 1 kg an acceleration of 1 m per second squared, and in the presented case this force was calculated to be 9500 N and it caused axial traction with incomplete decapitation. Biomechanical experiments[9] showed that traction forces of about 12,000 N led to complete decapitation irrespective of the diameter of the used halter. In another study the loading of the neck was estimated about 13,500 N,[11] and this value appears to be applicable to indicate the upper limit of tolerance of the neck.

In our case with 95 kg body mass and 3.1 m rope length, the final speed of the body was calculated to be 7.8 m/s (28 km/h), and the kinetic energy (Table 1) was 2945 Joule (J). The Joule is generally defined as the work done when the point of application of a force of 1 N is displaced a distance of 1 m in the direction of the force. We assumed a movement under the force (9500 N) of gravity only in free fall and zero starting speed. In the presented case soft tissue injuries, severance of ligaments, muscles, trachea, oesophagus, vessels, spinal cord injury with dissection between C2 and C3, fracture of hyoid bone and injuries of cartilages were found. There was no separation of the cervical skin, however, small amounts of bleeding were observed in the subcutis. This phenomenon provides evidence for the high stretching and tensile strength capability of skin and a significant resistance against dissection by blunt trauma.

We have considered how energy may be followed through a series of changes during the hanging process. First the energy is stored as gravitational potential energy $(E_p = mgy)$, and when a constant force acts on the body which is free to move, the mass accelerates (Fig. 4). During the free fall the energy is transformed into a new form, to kinetic energy $(E_k = 1/2\,mV^2)$. Finally, just before decapitation, the tissues of the neck and the rope are deformed as elastic forces are overcome, and the energy is stored as elastic potential energy of a stretched rope $(E_e = 1/2\,Fl)$, where l is the distance of extension. Based on the principle of the conservation of energy there is a transfer from decreasing potential energy to the increasing kinetic energy and elastic spring energy $(E_p = E_k = E_e)$. The energy is usually stored in the rope, the shape of which is changed when a force is applied to wind it up. Elastic expansion $(1/2Dl^2)$ depends on the distance (l) of extension, and it also

Table 1
Data from the literature in complete or incomplete decapitation due to hanging

Age/sex	Body mass (kg)	Distance of free fall, or length of rope (m)	Calculated values assuming free fall			Reference, type of decapitation
			F	v	E_k	
52/male	95	3.1	9500 N	7.8 m/s	2945 J	Our case incomplete decapitation
47/male	144	2	14400 N	6.3 m/s	2880 J	(1) Complete decapitation
22/male	87.5	3.77	8750 N	8.6 m/s	3235 J	(2) Complete decapitation
59/male	54	3.7	5400 N	8.6 m/s	1996 J	(3) Complete decapitation
52/male	90	3.8	9000 N	8.7 m/s	3406 J	(9) Complete decapitation

depends on the spring constant (D) characteristic for the rope and neck tissues. The final result of complete or incomplete decapitation can be caused by the high energy being continually transformed from one form to another during the falling. By climbing to a high place the force is gravitational and the energy stored as gravitational potential energy. The rope is deformed when wound up and the energy is stored in elastic potential energy. As the spring returns to its original shape, the energy produces decapitation.

The result of decapitation might depend on the distance of negative acceleration when the maximal speed of the falling body is reduced to zero, and the head of the body is held by the rope. In the terminal stage the hanging body can swing on a stretched rope, and the body can oscillate up and down. The characteristics of the rope must be taken into consideration in every case of incomplete or complete decapitation.

Based on the physical rules we concluded that the pathomechanism of decapitation during the hanging process had a complexity of movements and energy transfer. It will be more complicated by the stretching tissues in the neck. In Fig. 5 we present the schematic summary of the pathway of decapitation with stretching tissues working as a spring model. This figure demonstrates the decapitation process by the storing energies in hanging. From the starting position to the final position the victim changes the motion and the position of the body mass in a gravitational field. The final mechanism of decapitation caused by the stretching tissues in the neck and by the changes the shape of the rope as an elastic spring.

In Table 1 we summarised data of studies[1–3,9] presented complete decapitations. In these reports data of the body weight and the distance of free fall were available. Based on these values we calculated the force, the final speed and the kinetic energy compared with our case. The value of the height of the starting position is often mentioned in the presented cases, however, only the distance of falling can influence the movement and mechanism of complete or incomplete decapitation.

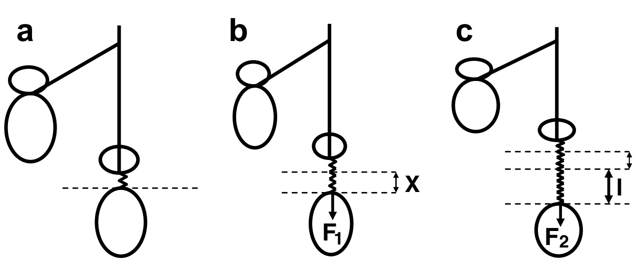

Fig. 5. Decapitation process in hanging. (a) Starting position of the victim by changing the position of the body mass in a gravitational field. Unstretched spring. (b) Terminal position by changing the motion of the body mass, and by changing the shape of the rope and neck tissues as an elastic spring. There is a small force (F_1) extends spring by a distance (x). (c) The pathomechanism of decapitation caused by the stretching tissues in the neck, store of energy as a spring model. Large force (F_2) causes decapitation extends spring by a distance (l). Energy stored: $E = 1/2Dl^2$.

The calculated physical parameters did not show any significant differences between our incomplete decapitation case and the other presented cases of complete decapitation. The force was calculated to be between 5400 and 14,400 N, and the stored energy varied by about 2000–3000 J. The complete mechanism of decapitation is a combination of the axial traction and the radial pressure of the tightening noose,[1] and mathematically this radial force is suggested to be $2Q$ (=6.28) times greater than the traction.[10] In our case we did not assume any rotation or circular motion, and in this way we cannot calculate with centripetal force that acts on the puck towards a centre of the circle of the neck. In our case the cervical skin was not ruptured, and we confirmed the previous findings that the axial traction was the predominant force in decapitation.[1,10]

A study[1] collected cases from the literature with complete decapitation due to suicidal hanging. Complete decapitation of hanging is very rare,[11–14] and only a few incomplete decapitations can be found among presented cases.[5] Rabl et al.[10] reviewed five cases with incomplete decapitation caused by suicidal hanging. Rothschild and Schneider[1] summarised the significant factors contributing to the complete decapitation as a result of suicidal hanging as heavy body weight, inelastic rope, and falling from a great height. Our results of scene investigation and autopsy findings confirmed the previous observations[1,4] as body weight and falling distance are the most important factors in the pathomechanism of decapitation during hanging process. We concluded that the occurrence of complete or incomplete decapitation can increase by the increasing energy stored as potential energy at the starting position, and the characteristics of the rope extended by the hanging body.

In most cases of the complete decapitation the scene was a bridge[2,3] or stairs.[1] The length of the hanging rope varied between 2.4 and 5 m,[1] and the body mass was between 54–184 kg.[3,14] The hanging materials were nylon rope, hemp rope, synthetic belt and a steel cable.[1]

Several pathomorphological changes can be detected in hanging cases with decapitation. Blood aspiration in the lungs,[4] petechial haemorrhages in the face[8] and the heart, as well as lung oedema[4] occur in most of the presented cases. Clavicle insertion haemorrhages of the sternomastoid muscles, congestive petechial bleeding can provide evidence of vital reactions in hanging cases.[6,14] Rothschild and Schneider[1] showed that suicides who jumped from an elevated position with a noose around their neck and fell from height may occasionally sustain cervical spine injuries, which will be in proportion to body weight and the distance of the fall. Zhu et al.[3] concluded that cervical spine fractures may be useful for the interpretation of the causal mechanisms of decapitation especially in cases of advanced decomposition or skeletonization. Feigin[7] found that approximately 9% of accidental or suicidal hangings showed neck organ fractures.

A detailed scene investigation, the evaluation of environmental circumstances and a careful post-mortem exam-

ination are essential for differentiation between accidental, homicidal and suicidal hanging with decapitation. The calculation of the energy transferred when the shape of human body is changed can be useful in the understanding of the pathomechanism of decapitation. In hanging process energy can be stored in several ways, for example, by changing the position of human body in the gravitational field, by changing the shape of hanging rope, and by changing the motion of hanging body. During the hanging process the energy is being continually transformed from one from to another.

In our study we presented a hanging case as a process based on a physics model, together the process provide a field of knowledge which raises questions about the nature of hanging. We can never make measurements with absolute precision in hanging cases. All the arithmetical calculations we made had some degree of uncertainty. The energy transferred from the potential energy to the kinetic energy can be compared in hanging cases. We have interpreted the constant force to a constant mass with the interchange of potential and kinetic energies during the hanging process.

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